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RESEARCH MEMORANDUM

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COOLING CHARACTERISTICS OF THE V-1650-7 ENGINE

II - EFFECT OF COOLANT CONDITIONS ON CYLINDER TEMPERATURES AND HEAT REJECTION AT SEVERAL ENGINE POWERS

By John H. Povolny, Louis J. Bogdan
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Flight Propulsion Research Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

An investigation has been conducted on a V-1650-7 engine to determine the cylinder temperatures and the coolant and oil heat rejections over a range of coolant flows (50 to 200 gal/min) and oil inlet temperatures (160° to 215° F) for two values of coolant outlet temperature (250° and 275° F) at each of four power conditions ranging from approximately 1100 to 2000 brake horsepower. Data were obtained for several values of block-outlet pressure at each of the two coolant outlet temperatures. A mixture of 30 percent by volume of ethylene glycol and 70-percent water was used as the coolant.

The effect of varying coolant flow, coolant outlet temperature, and coolant outlet pressure over the ranges investigated on cylinder-head temperatures was small (0° to 25° F) whereas the effect of increasing the engine power condition from 1100 to 2000 brake horsepower was large (maximum head-temperature increase, 110° F).

INTRODUCTION

At the request of the Air Materiel Command, Army Air Forces, an investigation to determine the cooling characteristics of the V-1650-7 engine was conducted at the NACA Cleveland laboratory during the spring and summer of 1946. The coolant-flow distribution, cylinder temperatures, and the coolant and oil heat rejections at several standard power levels are presented in

reference 1 for a coolant mixture of 30-percent ethylene glycol and 70-percent water. The investigation reported herein was conducted to determine the effect of varying the coolant conditions and the oil inlet temperature on the cylinder temperatures and on the coolant and oil heat rejections. Data were obtained at several coolant outlet temperatures and several coolant outlet pressures for a range of coolant flows and for a range of oil inlet temperatures at each of three engine power conditions varying from normal rated to war emergency power. In addition, data were also obtained at several coolant outlet pressures for a range of coolant flows at a constant coolant outlet temperature and an engine power of 2000 brake horsepower. A mixture of 30-percent ethylene glycol and 70-percent water was used as the coolant for this investigation.

APPARATUS

The investigation was conducted on a standard production model V-1650-7 engine. This engine is equipped with a two-stage, two-speed supercharger having impeller diameters of 12.0 and 10.1 inches and gear ratios of 5.802:1 and 7.349:1. The engine is equipped with a liquid-type aftercooler and a variable-spark mechanism, which is connected to the throttle. A more complete description of the engine is given in reference 1.

The engine was mounted on the 3000-horsepower dynamometer stand illustrated in figure 1 and the engine coolant, oil, and aftercooler coolant were supplied to it by means of the auxiliary systems shown in figures 2, 3, and 4, respectively. These systems are also described in detail in reference 1. The exhaust and combustion-air systems used were the same as those described in reference 1.

A mixture of 30-percent ethylene glycol and 70-percent water with 0.2 percent by volume of sodium mercaptobenzothiazole (NaMBT) added as a corrosion inhibitor was used as the coolant. Navy 1120 lubricating oil was used for lubrication and AN-F-28, Amendment-2, fuel was used for combustion. Knock-free engine operation was obtained at high powers by adding 3 percent by volume of xylidines to the fuel and increasing the tetraethyl-lead concentration to 6 milliliters per gallon.

Thermocouples were located in each cylinder between the exhaust valves, between the intake valves, in the center of the head, at the top of the cylinder barrel on the exhaust side, and on the exhaust spark-plug gasket. The installation of the thermocouples on the engine was the same as that described in reference 1 and is shown in figures 5 and 6.

PROCEDURE

Cylinder temperatures, and coolant and oil heat rejections were determined for the engine powers and over the ranges of coolant conditions listed in table I. At coolant outlet temperatures of approximately 250° and 275° F, a range of coolant flows from approximately 50 to 200 gallons per minute and a range of oil inlet temperatures from approximately 160° to about 215° F were independently investigated for each of the following three power conditions: (1) normal rated; (2) take-off; and (3) war emergency.

At a coolant outlet temperature of 250° F, a range of coolant flows from about 50 to about 200 gallons per minute was also investigated for an engine power condition of 2000 brake horsepower and 3200 rpm. For every variable coolant-flow run, data were taken at each of three coolant outlet pressures. The manifold temperatures given by the manufacturer for the rated power (table I) were obtained by regulating the aftercooler coolant flow and temperature.

For the entire investigation reported, the following conditions were maintained constant:

Carburetor-air temperature °F	80 ± 2
Carburetor and exhaust pressure	Atmospheric
Supercharger setting	Low blower
Spark timing, deg B.T.C.	45 ± 1

The heat rejections to the coolant and the oil were determined from both the measured flow and the temperature rise of the coolant and oil and from the measured flow and temperature rise of the respective cooling waters.

RESULTS AND DISCUSSION

Cylinder-Temperature Data

The variation of the average and the maximum cylinder-head temperature measured between the exhaust valves with coolant flow for several coolant outlet pressures and power conditions, and two coolant outlet temperatures is presented in figures 7 and 8, respectively. The maximum temperature measured between the exhaust valves (fig. 8) is the highest temperature measured anywhere on the cylinder for every set of engine and cooling conditions presented. The highest temperature measured was 678° F and

it occurred at 2000 brake horsepower for a coolant flow of 52 gallons per minute, a coolant outlet temperature of 250° F, and a coolant outlet pressure of 40 pounds per square inch. (See fig. 8(d).) The maximum temperatures are from about 30° to 70° F higher than the average temperatures.

The variation of the average temperatures measured in the center of the heads, between the intake valves, on the exhaust spark-plug gaskets, and at the top of the barrels on the exhaust side for the same conditions as the temperature data measured between the exhaust valves is presented in figures 9, 10, 11, and 12, respectively. The average cylinder-head temperature measured in the center of heads (fig. 9) is about 65° F lower than that between the exhaust valves (fig. 7). The average temperature measured between the intake valves (fig. 10) is lower than that between the exhaust valves (approximately 90° F) or than that in the center of the head (approximately 25° F). The average spark-plug-gasket temperature (fig. 11) is about 55° F lower than that between the exhaust valves. The average temperature measured at the top of the barrels on the exhaust side (fig. 12) is considerably lower than that measured in the other locations, ranging from approximately 260° to 330° F lower than the average temperature between the exhaust valves for the range of conditions investigated.

Effect of coolant flow. - The effect of coolant flow on cylinder temperatures was small. The maximum increase in the average temperature measured between the exhaust valves (fig. 7) was 13° F for a decrease in coolant flow from 200 to 50 gallons per minute. The rate of increase in temperature with decrease in coolant flow was generally greater in the range of coolant flows from 100 to 50 gallons per minute than in the range from 200 to 100 gallons per minute. The greatest increase in temperature with decrease in coolant flow from 100 to 50 gallons per minute amounted to about 20° F in the maximum cylinder-head temperature (fig. 8).

The increase in the average temperature measured in the center of the heads (fig. 9) with decreasing coolant flow is slightly greater at 2000 brake horsepower (about 24° F for a change in flow from 200 to 50 gal/min) than in the cylinder head between the exhaust valves. The effects of coolant flow on the average temperature measured in the center of the heads and between the intake valves (fig. 10) are, however, generally similar to the effects of coolant flow on the average temperature measured

between the exhaust valves. The effect of coolant flow on the average temperature of the exhaust spark-plug gasket (fig. 11) and on the average temperature measured at the top of the barrels (fig. 12) was negligible.

The lesser effect of coolant flow in the flow range from 200 to 100 gallons per minute is partly due to the decrease in average coolant temperature with decreased flow resulting from the approximately constant coolant heat rejection obtained when the coolant outlet temperature is held constant and is also partly due to localized nuclear boiling of the coolant.

The greater effect of coolant flow in the flow range from 100 to 50 gallons per minute is the result of a transition from nuclear to film-type boiling wherein insulating vapors are formed resulting in a decrease in the heat-transfer coefficient and a large increase in cylinder temperature. This transition would be expected to be more pronounced in the hotter cylinders and in the hotter region of each cylinder and would depend upon coolant conditions such as flow, pressure, temperature, and composition.

Effect of coolant outlet pressure. - Increasing the coolant outlet pressure generally caused an increase in the cylinder temperatures and presents evidence that some boiling of the coolant occurred during this investigation.

For all conditions investigated, the effect of coolant outlet pressure was small; the maximum increase in average cylinder-head temperature measured between the exhaust valves (fig. 7) amounted to approximately 14° F for an increase in coolant outlet pressure of about 20 pounds per square inch. The effects on the average temperature measured in the center of the heads (fig. 9) and the average spark-plug-gasket temperature (fig. 11) were similar to that on the average temperature between the exhaust valves. The change in coolant outlet pressure had a slightly greater effect on the maximum temperature measured between the exhaust valves (fig. 8) and a lesser effect on the average temperature measured between the intake valves (fig. 10) than on the average temperature measured between the exhaust valves. The effect on the average temperature measured at the top of the barrels (fig. 12) was negligible.

Effect of coolant outlet temperature. - The increase in the cylinder-head temperature measured between the exhaust valves (fig. 7) for a change in coolant outlet temperature from 250° to 275° F was generally 25° F. This effect was reduced at war

emergency power (1670 to 1700 bhp). The effects of coolant outlet temperature on the maximum cylinder-head temperature (fig. 8), and the average temperatures measured in the center of the head (fig. 9), between the intake valves (fig. 10), and on the exhaust spark-plug gasket (fig. 11) are similar to those on the average temperature in the cylinder head between the exhaust valves. The change in the average cylinder temperature measured at the top of the barrels (fig. 12) was about 20° F.

Effect of engine power. - The increase in average cylinder-head temperature measured between the exhaust valves (fig. 7) with a change in the engine power condition from approximately 1100 to 2000 brake horsepower generally amounted to about 75° F; the largest increase in the maximum cylinder-head temperature between the exhaust valves (fig. 8) amounted to about 110° F (from 566° to 678° F) for the same change in engine power condition. The increases in the average temperatures measured in the center of the cylinder head (fig. 9), between the intake valves (fig. 10), and on the exhaust spark-plug gaskets (fig. 11) were about 65°, 50°, and 70° F, respectively. This change in engine power had no effect on the average temperature measured at the top of the barrels (fig. 12).

Effect of oil inlet temperature. - The variation of the average cylinder-head temperature measured between the exhaust valves with oil inlet temperature is shown in figure 13 for two coolant outlet temperatures at each of three power conditions. The oil inlet temperature had no effect on the average cylinder-head temperature for any of the conditions tested. The increase in average cylinder-head temperature caused by increasing the coolant outlet temperature from 250° to 275° F was greater than that noted for figure 7 and is due to increasing cylinder temperatures with engine running time. The effects of engine running time are discussed in the following section.

Effect of engine running time. - During the course of this investigation and also that reported in reference 1, a continuous increase of the cylinder-head temperatures in certain locations with engine running time was noted. The variation of the average temperatures measured in various locations of the cylinders with engine running time is illustrated in figure 14. In an interval of about 100 hours running time, an increase of about 45° F in the average temperature of the cylinder heads between the exhaust valves and in the center of the heads is noted, whereas no increase is noted for the region between the intake valves or for the exhaust spark-plug gasket. Inspection of the coolant passages of a

scrapped cylinder head showed extensive scale deposits in the center and on the exhaust side of the head but none on the intake side of the head. This scale, in all probability, is responsible for the variations in cylinder-head temperature obtained with engine running time. Although the data are not corrected to a reference engine running time, the trends indicated by the curves (figs. 8 to 13) are correct (except as noted for fig. 13) because the data showing the effects of the different variables were taken within a short elapsed interval of running time.

Heat-Rejection Data

The heat balance between the coolant and coolant-cooling water and the oil and oil-cooling water is shown in figure 15; satisfactory agreement is noted. The variations of the coolant and oil heat rejections with coolant flow for two coolant outlet temperatures and various values of engine power are presented in figure 16. Both the coolant and the oil heat rejections are unaffected by coolant flow with the exception of the runs at 2000 brake horsepower for which a decrease in the coolant heat rejection of about 700 Btu per minute occurred for a decrease in coolant flow from 200 to 50 gallons per minute. This drop in coolant heat rejection is probably the result of the increased resistance to heat transfer attendant with the transition from nuclear to film-type boiling (previously discussed) in localized hot spots in the cylinder heads. An increase in the coolant outlet temperature from 250° to 275° F in general resulted in a decrease of about 400 Btu per minute in the coolant heat rejection, which was accompanied by a corresponding increase in the oil heat rejection. For a change in engine power from approximately 1100 to 2000 brake horsepower, the coolant heat rejection increased approximately 7000 Btu per minute (from about 18,000 to about 25,000 Btu/min) and the oil heat rejection increased approximately 2700 Btu per minute (from 2800 to about 5500 Btu/min).

The variation of the coolant and oil heat rejections with oil inlet temperature for two coolant outlet temperatures and several engine powers is presented in figure 17. For an increase in the oil inlet temperature from 160° to 210° F, a decrease of about 1000 Btu per minute in the oil heat rejection occurred in every case and the coolant heat rejection remained unaffected.

Inasmuch as an increase in cylinder-head temperature occurred with coolant outlet pressure and engine running time as previously discussed, a corresponding decrease in coolant heat rejection would be expected. The limitations of the instrumentation did not, however, permit detection of any change in heat rejection with variable coolant outlet pressure or with engine running time.

SUMMARY OF RESULTS

The results of an investigation of the cooling characteristics of the V-1650-7 engine conducted over a range of engine powers from 1085 to 2000 brake horsepower for various coolant and oil conditions with a mixture of 30-percent ethylene glycol and 70-percent water as the coolant, indicated that:

1. The effect of coolant flow on the average cylinder temperatures was small and varied from position to position in the cylinder. For a decrease in coolant flow from 200 to 50 gallons per minute, the increase in the average cylinder temperature ranged from practically 0° F at the top of the cylinder barrel on the exhaust side to about 24° F in the center of the cylinder head. Both the coolant and oil heat rejections were unaffected by coolant flow for all conditions except at 2000 brake horsepower for which a decrease in the coolant heat rejection of about 700 Btu per minute occurred for a decrease in the coolant flow from 200 to 50 gallons per minute.

2. The effect of coolant outlet pressure on the cylinder temperature was small; the maximum increase in average cylinder-head temperature measured between the exhaust valves was 14° F for an increase in pressure of 20 pounds per square inch. The coolant and oil heat rejections were apparently unaffected by variation in coolant outlet pressure for all conditions investigated.

3. For a change in coolant outlet temperature from 250° to 275° F, the increase in the average cylinder-head temperature between the exhaust valves was generally 25° F. This effect was reduced at war emergency engine power. The corresponding change in the coolant heat rejections for the increase in coolant outlet temperature from 250° to 275° F amounted to a decrease of about 400 Btu per minute. In every case this drop in coolant heat rejection resulted in a corresponding increase of the oil heat rejection.

4. An increase in the oil inlet temperature from 160° to 210° F decreased the oil heat rejection about 1000 Btu per minute for all conditions tested but the cylinder-head temperatures and the coolant heat rejection remained unaffected.

5. A change in engine power condition from about 1100 to 2000 brake horsepower resqulted in increases in the cylinder temperatures ranging from practically 0° F at the top of the barrel on the exhaust side to about 110° F (from 566° to 678° F) on the hottest cylinder in the region between the exhaust valves. For the same

increase in power, the coolant heat rejection increased 7000 Btu per minute (from about 18,000 to about 25,000 Btu/min) and the oil heat rejection increased 2700 Btu per minute (from about 2800 to 5500 Btu/min).

6. The temperatures in the cylinder head between the exhaust valves and in the center of the cylinder heads were found to increase with engine running time. An increase of about 45° F in the average cylinder-head temperature for these regions occurred over a period of engine running time of about 100 hours.

Flight Propulsion Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio.

John H. Povolny

John H. Povolny,
Mechanical Engineer.

Louis J. Bogdan

Louis J. Bogdan,
Mechanical Engineer.

Louis J. Chelko

Louis J. Chelko,
Aeronautical Engineer.

Approved:

Eugene J. Manganiello,
Mechanical Engineer.

Benjamin Pinkel,
Physicist.

REFERENCE

1. Povolny, John H. and Bogdan, Louis J.: Cooling Characteristics of the V-1650-7 Engine. I - Coolant-Flow Distribution, Cylinder Temperatures, and Heat Rejections at Typical Operating Conditions. NACA RM No. E7E02, Army Air Forces, 1947.

TABLE I - SUMMARY OF TEST CONDITIONS

Power condition	Manifold pressure (in. Hg absolute)	Engine speed (rpm)	Measured engine power (bhp)	Fuel-air ratio	Manifold temperature (°F)	Coolant outlet temperature (°F)	Coolant outlet pressure (lb/sq in. gage)	Coolant flow (gal/min)	Oil inlet temperature (°F)
Normal rated	46	2700	1085	0.077	158	250	20,30,40	50-200	171
Normal rated	46	2700	1110	.077	136	275	27,35,45	49-202	171
Normal rated	46	2700	1100	.077	133	250	35	167	161-216
Normal rated	46	2700	1100	.076	140	275	40	167	158-215
Take-off	61	3000	1530	.093	170	250	20,30,40	49-200	172
Take-off	61	3000	1530	.090	170	275	28,35,45	51-206	172
Take-off	61	3000	1535	.090	161	250	35	167	161-216
Take-off	61	3000	1535	.090	165	275	40	167	160-216
War emergency	67	3000	1700	.090	175	250	22,30,40	50-205	171
War emergency	67	3000	1670	.090	175	275	28,35,45	76-202	171
War emergency	67	3000	1700	.090	168	250	35	167	160-212
War emergency	67	3000	1700	.090	175	275	40	167	158-215
High power	78	3200	2000	.092	175	250	20,30,40	52-201	170
Normal rated	46	2700	1110	.080	190	245	35	200	170

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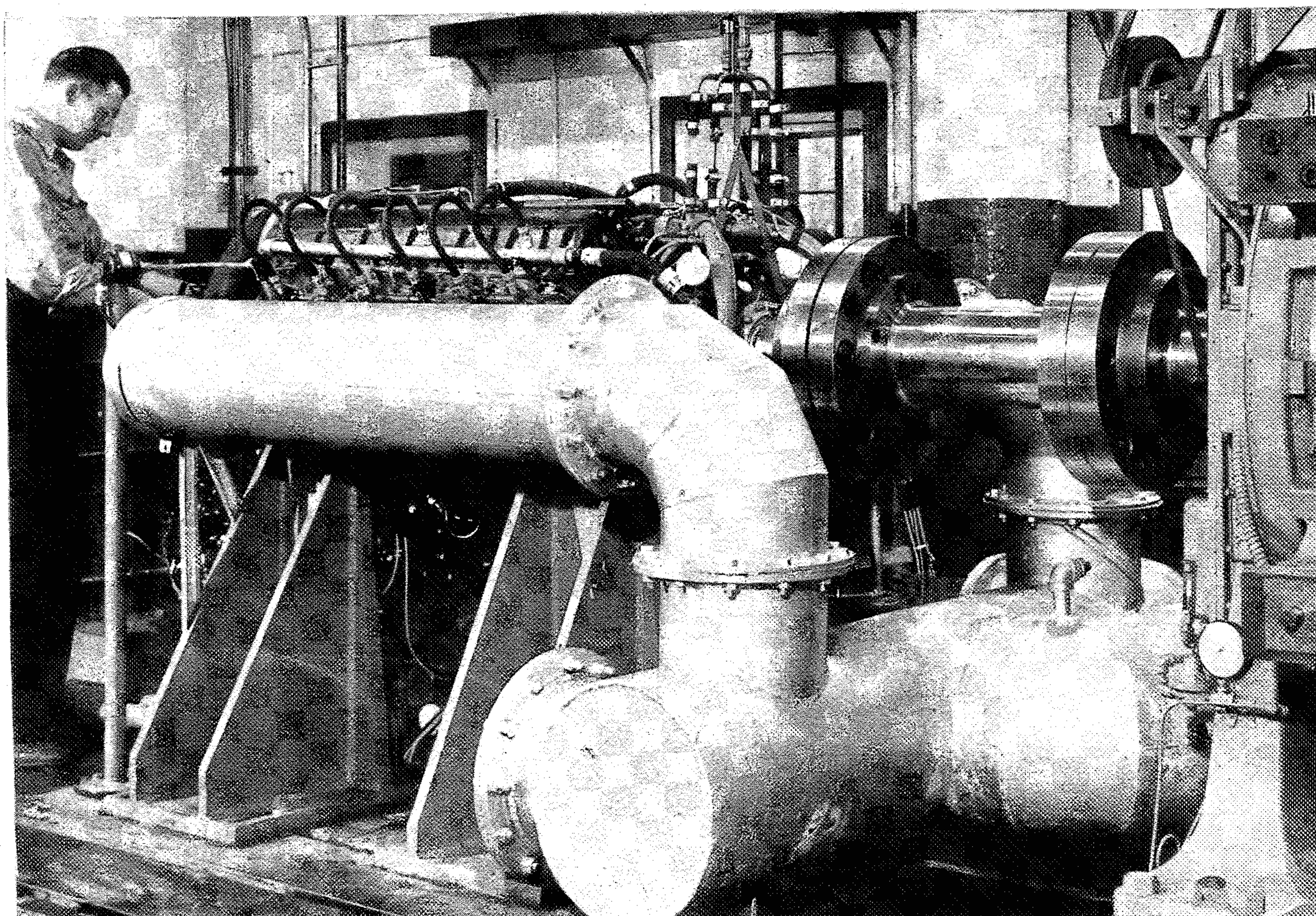

Figure 1. - Engine mounted for cooling investigation.

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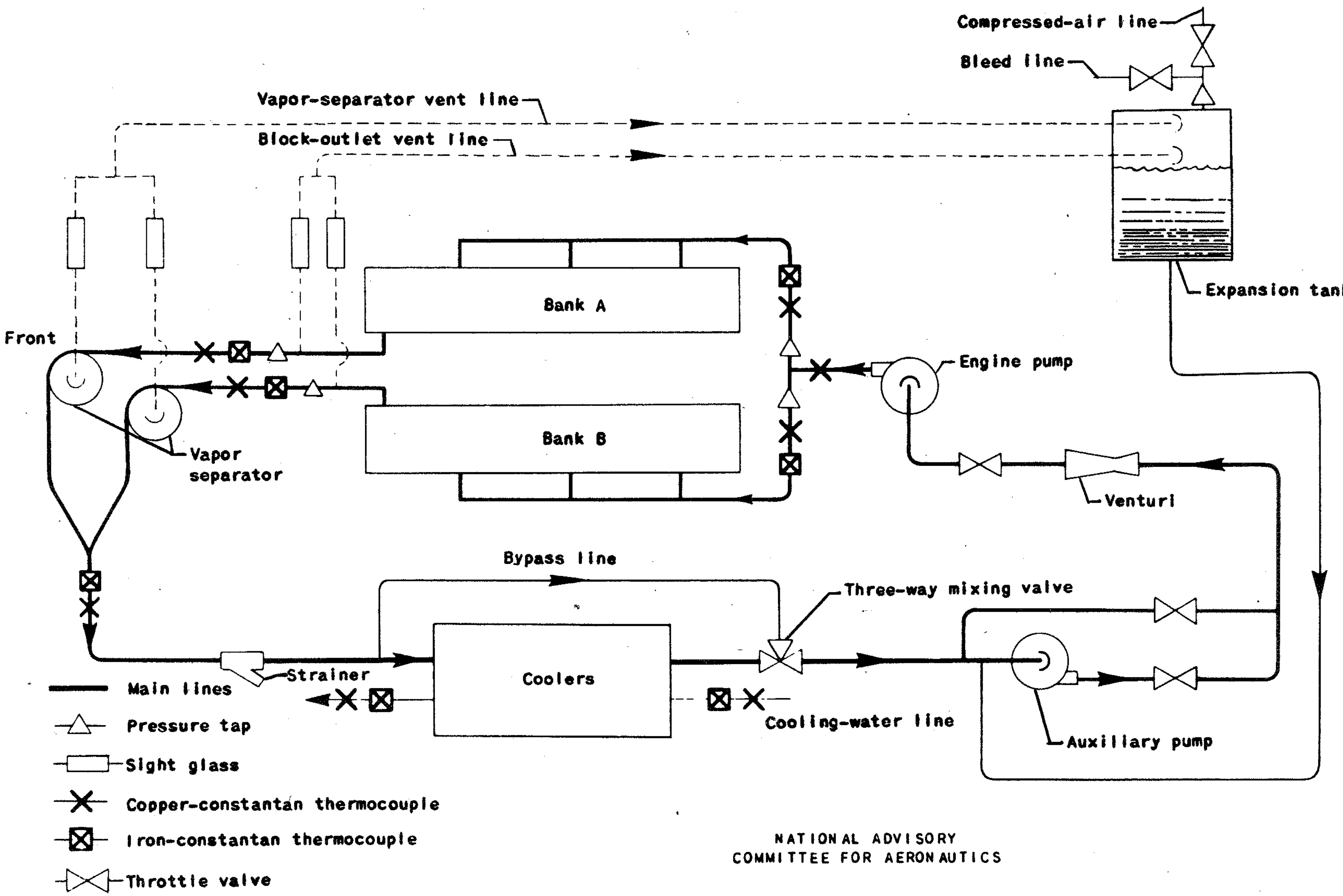

Figure 2. - Schematic diagram of engine-coolant system.

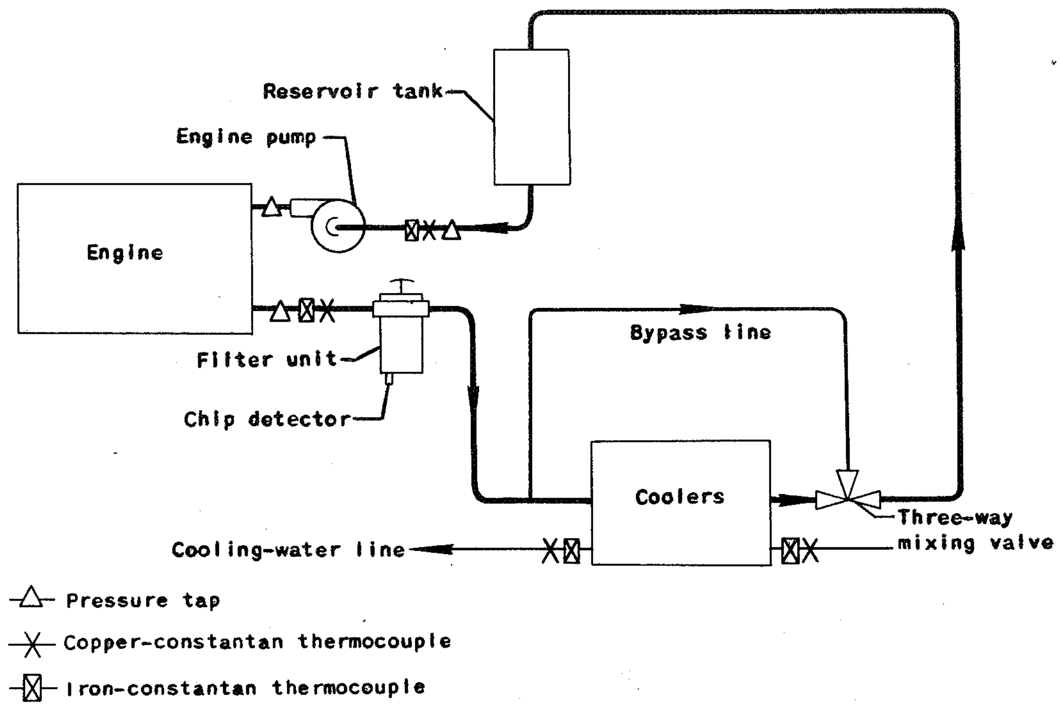

Figure 3. - Schematic diagram of lubricating-oil system.

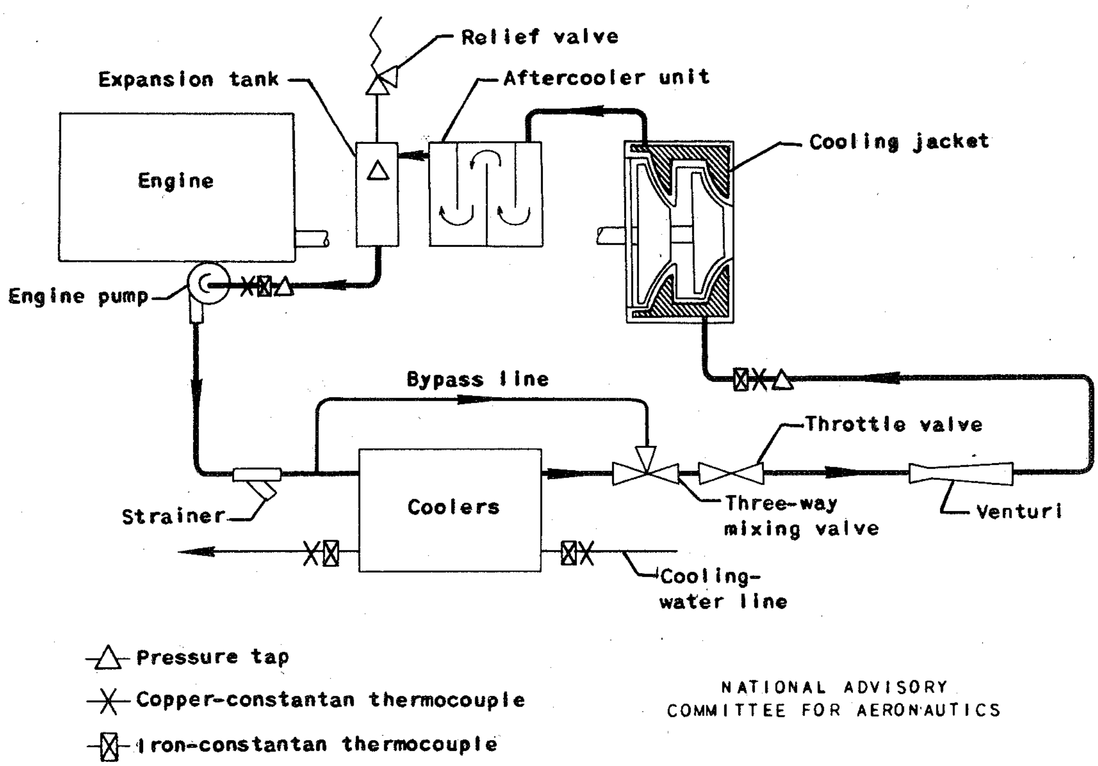

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Figure 4. - Schematic diagram of aftercooler-coolant system.

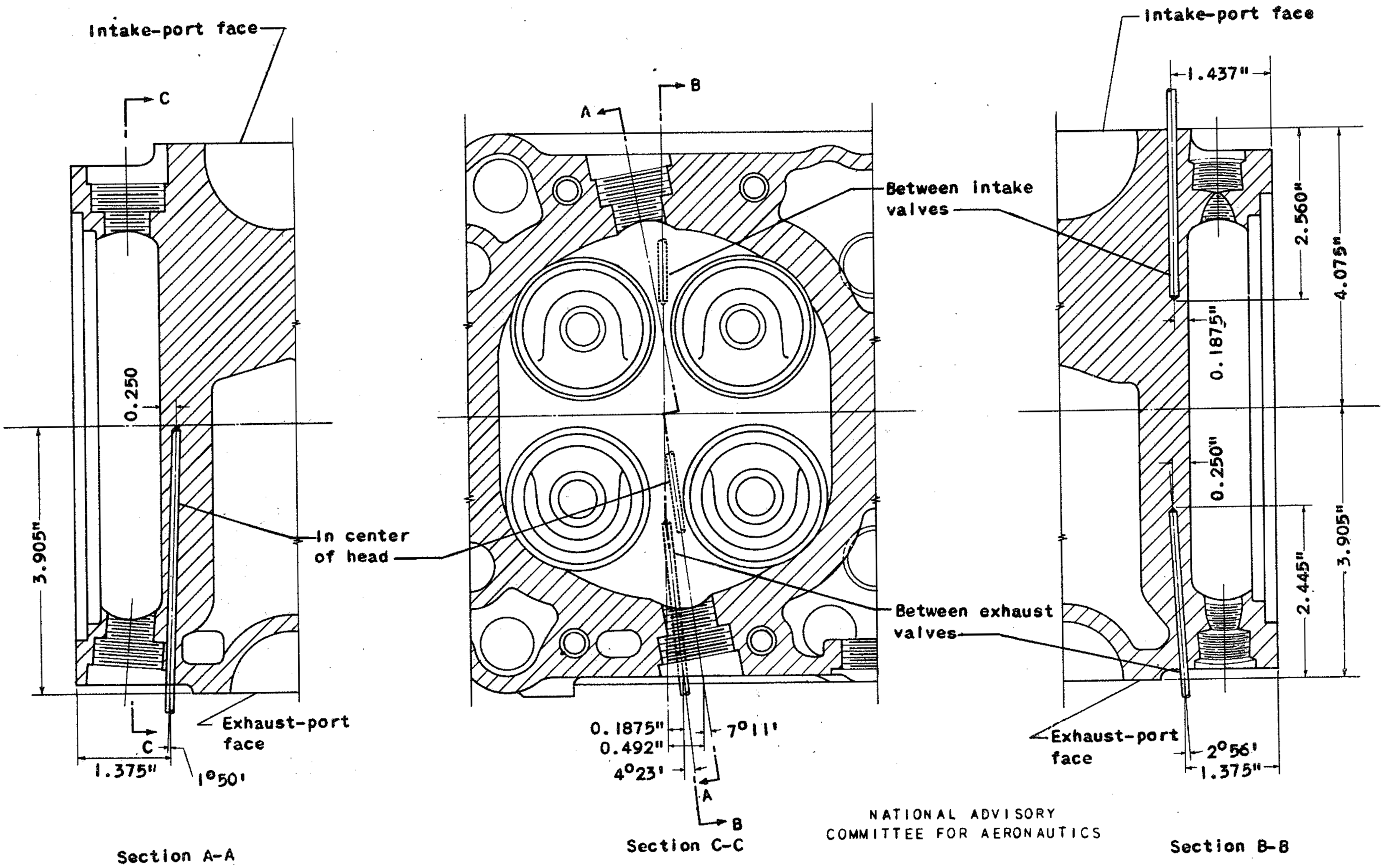

Figure 5. - Installation of cylinder-head thermocouples.

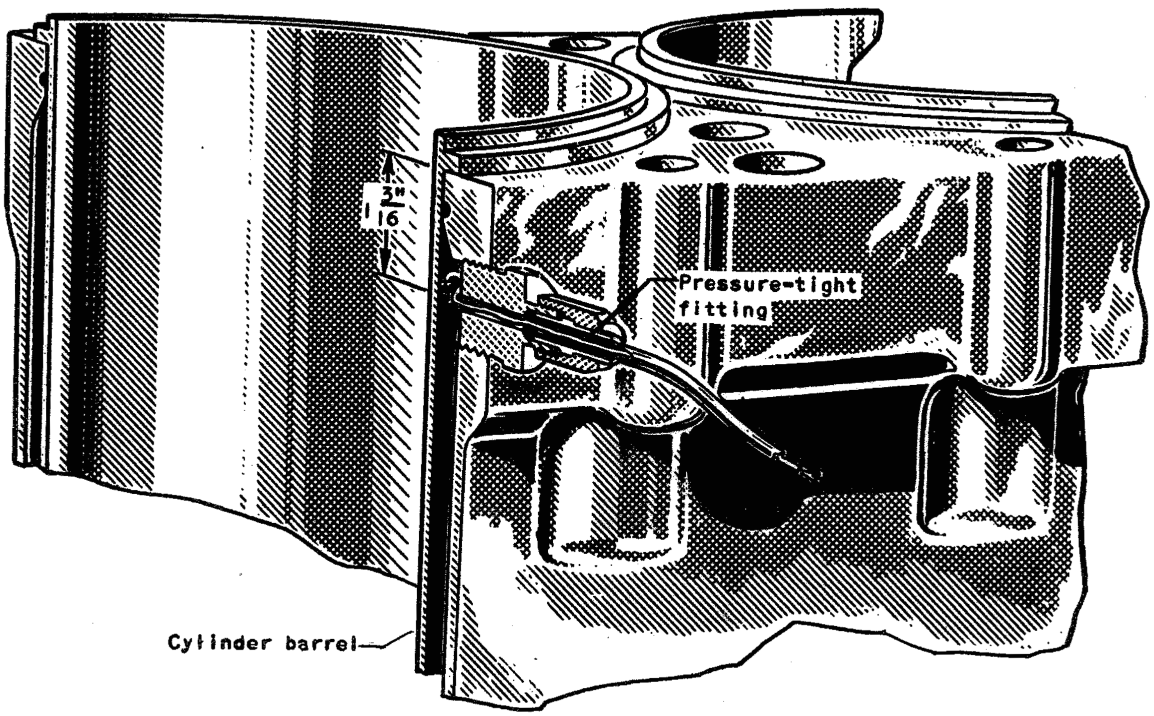

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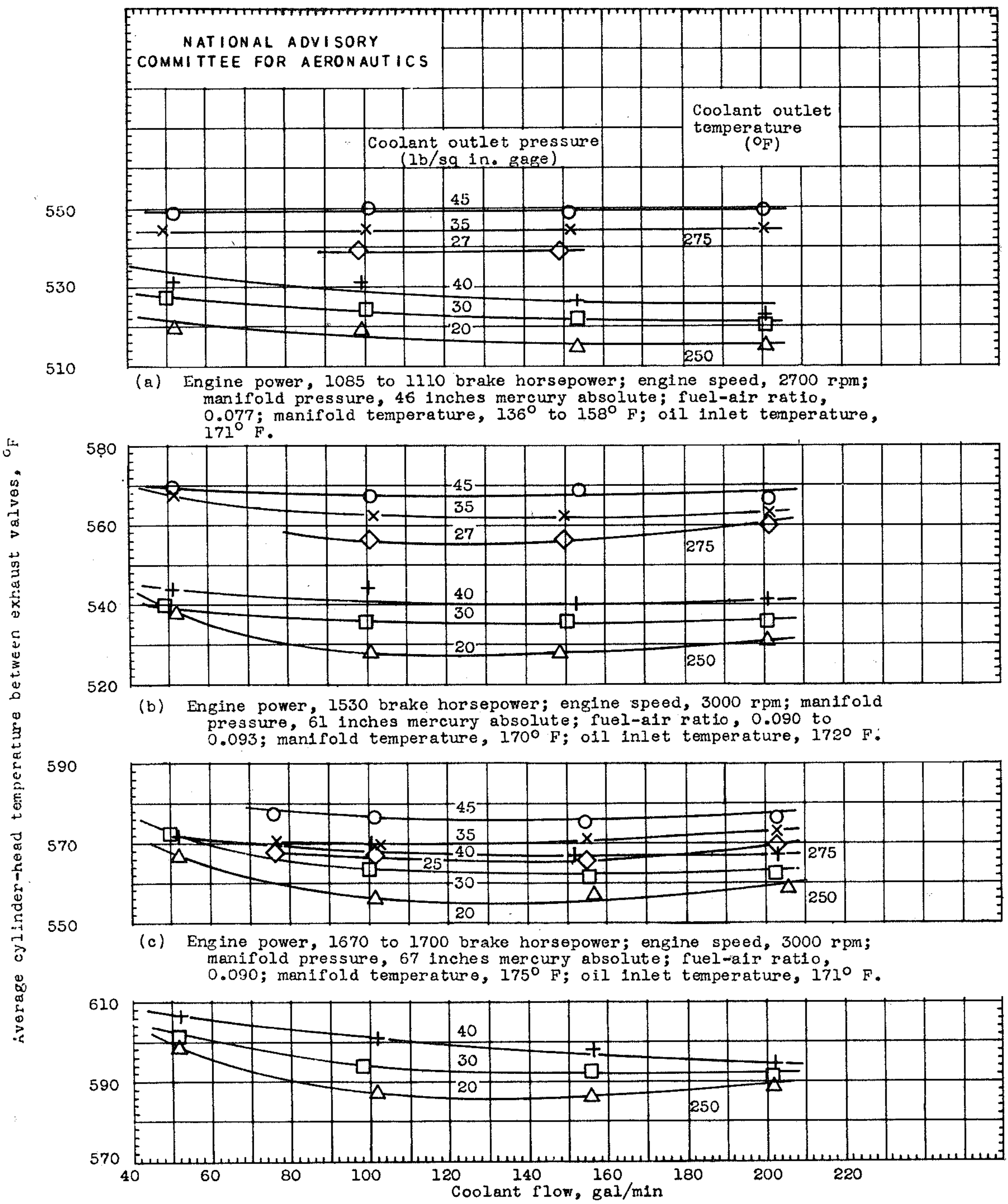
Figure 6. - Installation of thermocouple at top of barrel on exhaust side.



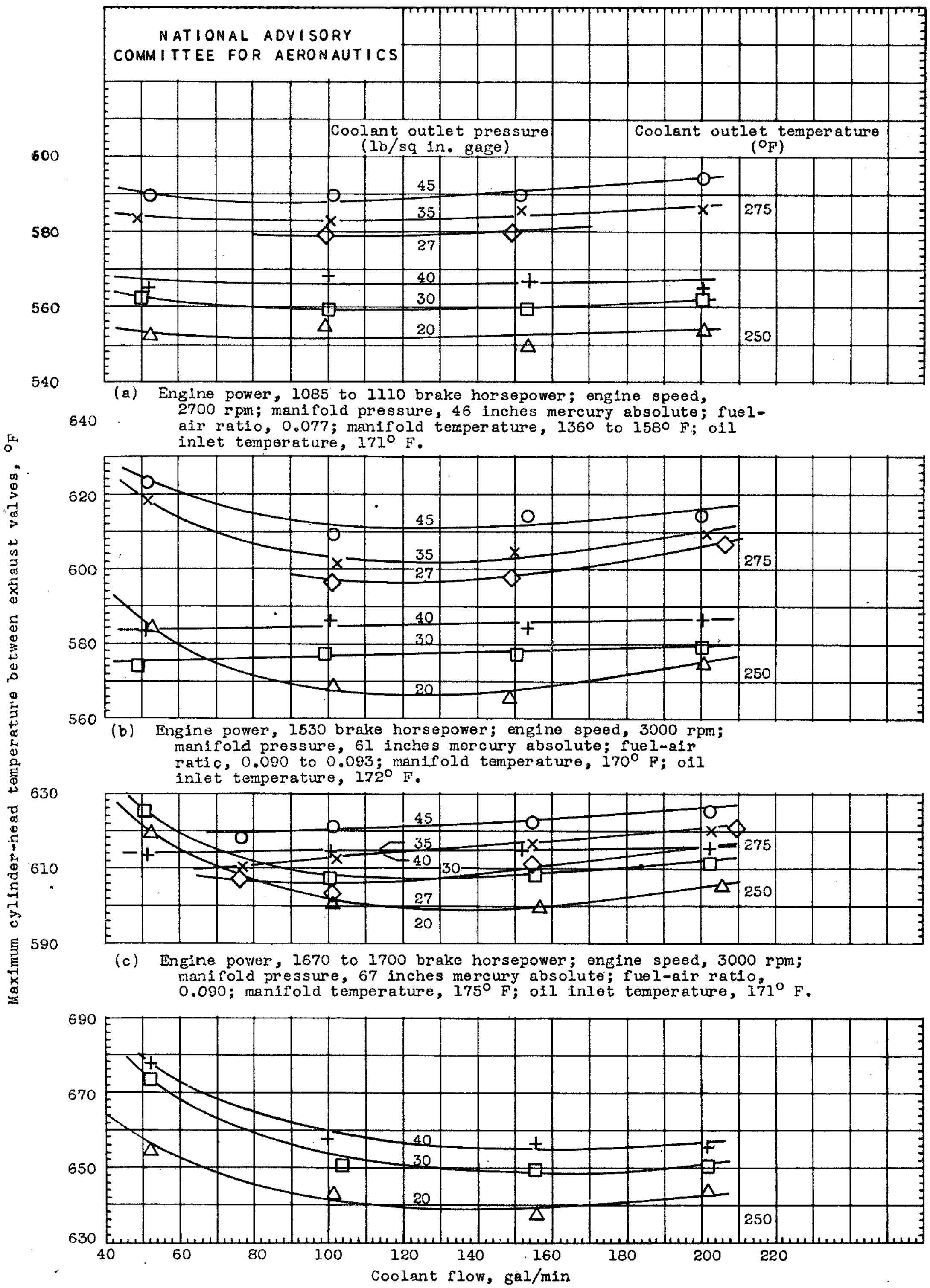
(a) Engine power, 1085 to 1110 brake horsepower; engine speed, 2700 rpm; manifold pressure, 46 inches mercury absolute; fuel-air ratio, 0.077; manifold temperature, 136° to 158° F; oil inlet temperature, 171° F.

(b) Engine power, 1530 brake horsepower; engine speed, 3000 rpm; manifold pressure, 61 inches mercury absolute; fuel-air ratio, 0.090 to 0.093; manifold temperature, 170° F; oil inlet temperature, 172° F.

(c) Engine power, 1670 to 1700 brake horsepower; engine speed, 3000 rpm; manifold pressure, 67 inches mercury absolute; fuel-air ratio, 0.090; manifold temperature, 175° F; oil inlet temperature, 171° F.

(d) Engine power, 2000 brake horsepower; engine speed, 3200 rpm; manifold pressure, 78 inches mercury absolute; fuel-air ratio, 0.092; manifold temperature, 175° F; oil inlet temperature, 170° F.

Figure 7. - Variation of average cylinder-head temperature between exhaust valves with coolant flow for several power conditions.



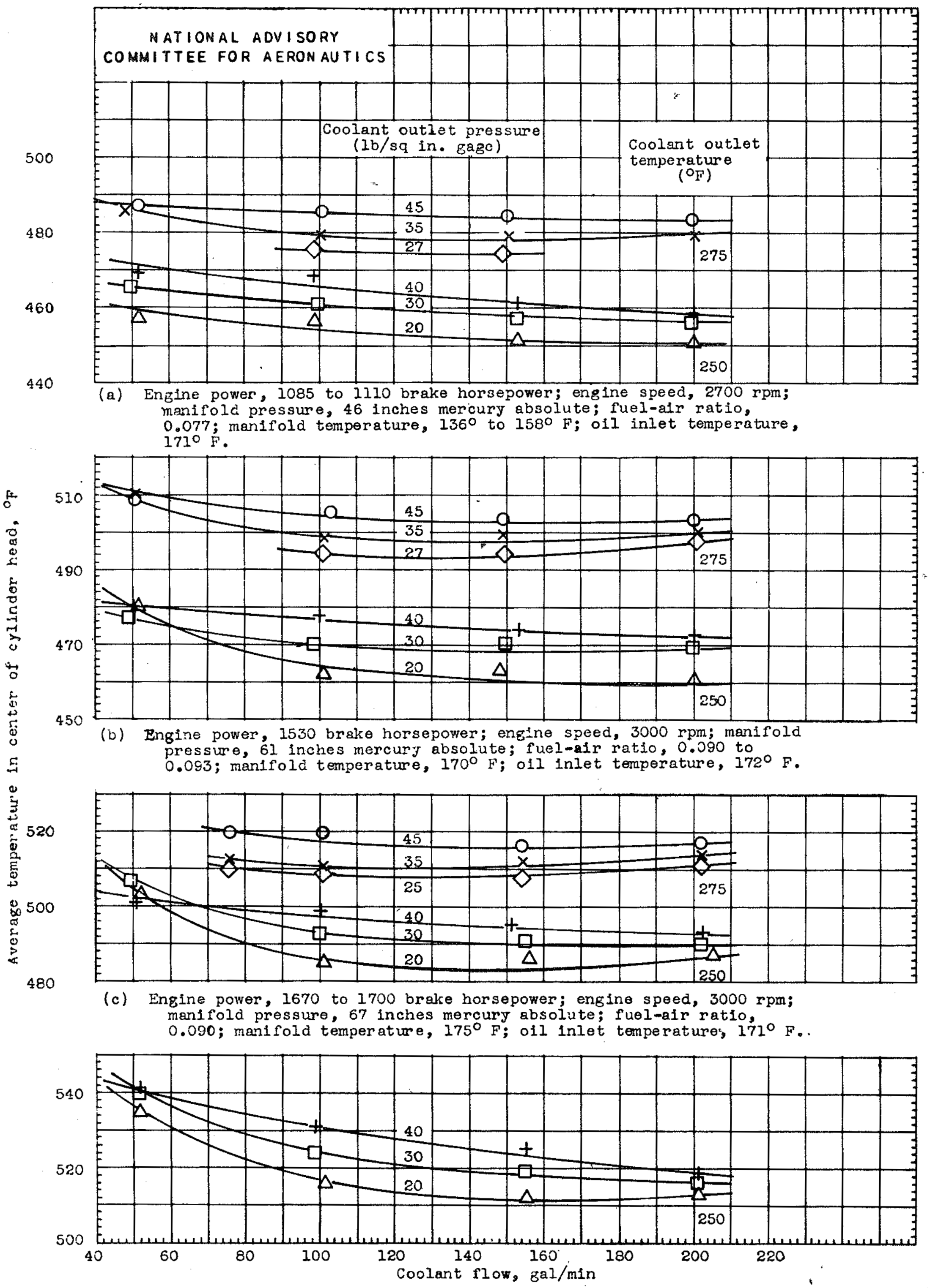
(a) Engine power, 1085 to 1110 brake horsepower; engine speed, 2700 rpm; manifold pressure, 46 inches mercury absolute; fuel-air ratio, 0.077; manifold temperature, 136° to 158° F; oil inlet temperature, 171° F.

(b) Engine power, 1530 brake horsepower; engine speed, 3000 rpm; manifold pressure, 61 inches mercury absolute; fuel-air ratio, 0.090 to 0.093; manifold temperature, 170° F; oil inlet temperature, 172° F.

(c) Engine power, 1670 to 1700 brake horsepower; engine speed, 3000 rpm; manifold pressure, 67 inches mercury absolute; fuel-air ratio, 0.090; manifold temperature, 175° F; oil inlet temperature, 171° F.

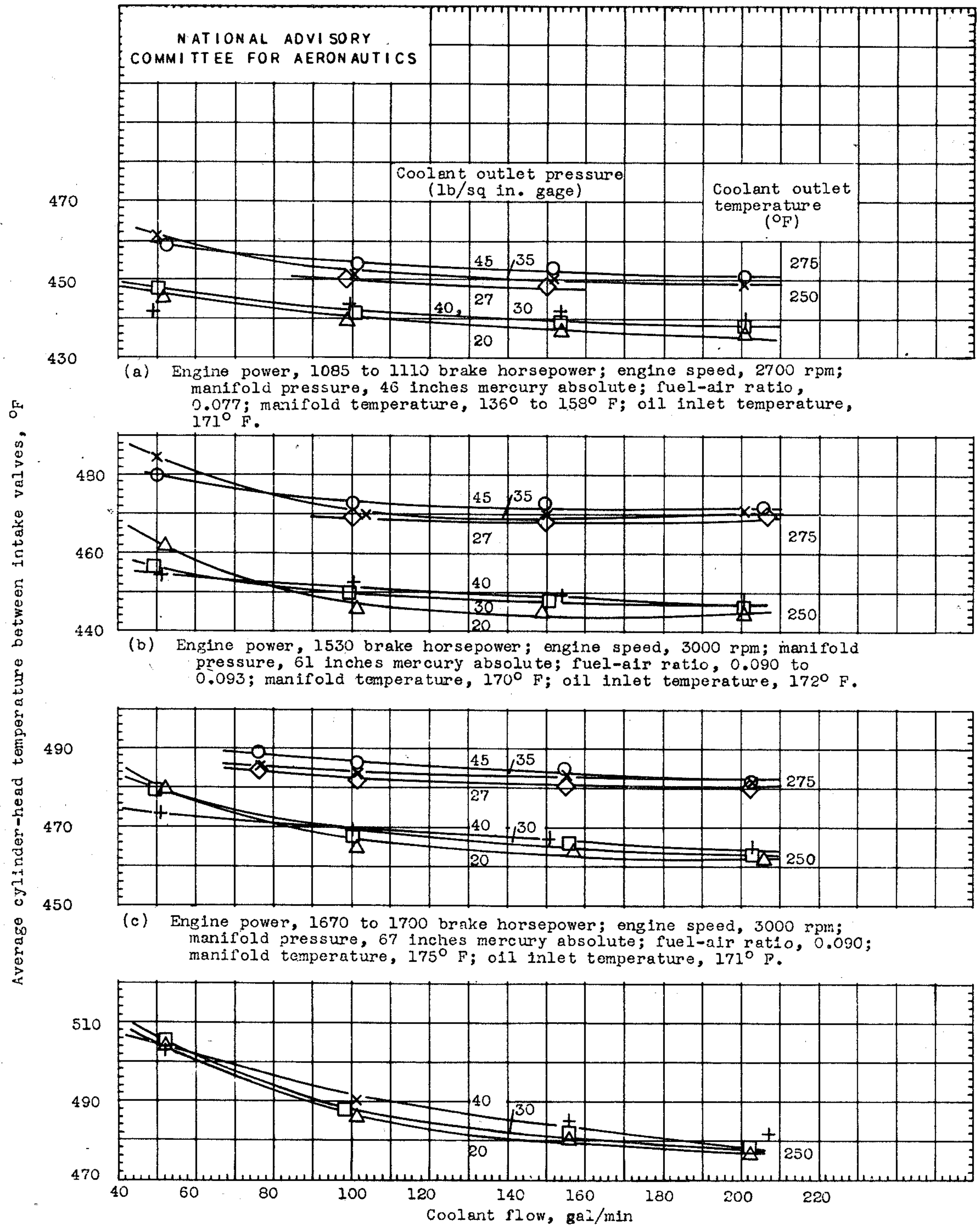
(d) Engine power, 2000 brake horsepower; engine speed, 3200 rpm; manifold pressure, 78 inches mercury absolute; fuel-air ratio, 0.092; manifold temperature, 175° F; oil inlet temperature, 170° F.

Figure 8. - Variation of maximum cylinder-head temperature between exhaust valves with coolant flow for several power conditions.



(d) Engine power, 2000 brake horsepower; engine speed, 3200 rpm; manifold pressure, 78 inches mercury absolute; fuel-air ratio, 0.092; manifold temperature, 175° F; oil inlet temperature, 170° F.

Figure 9. - Variation of average temperature in center of cylinder head with coolant flow for several power conditions.



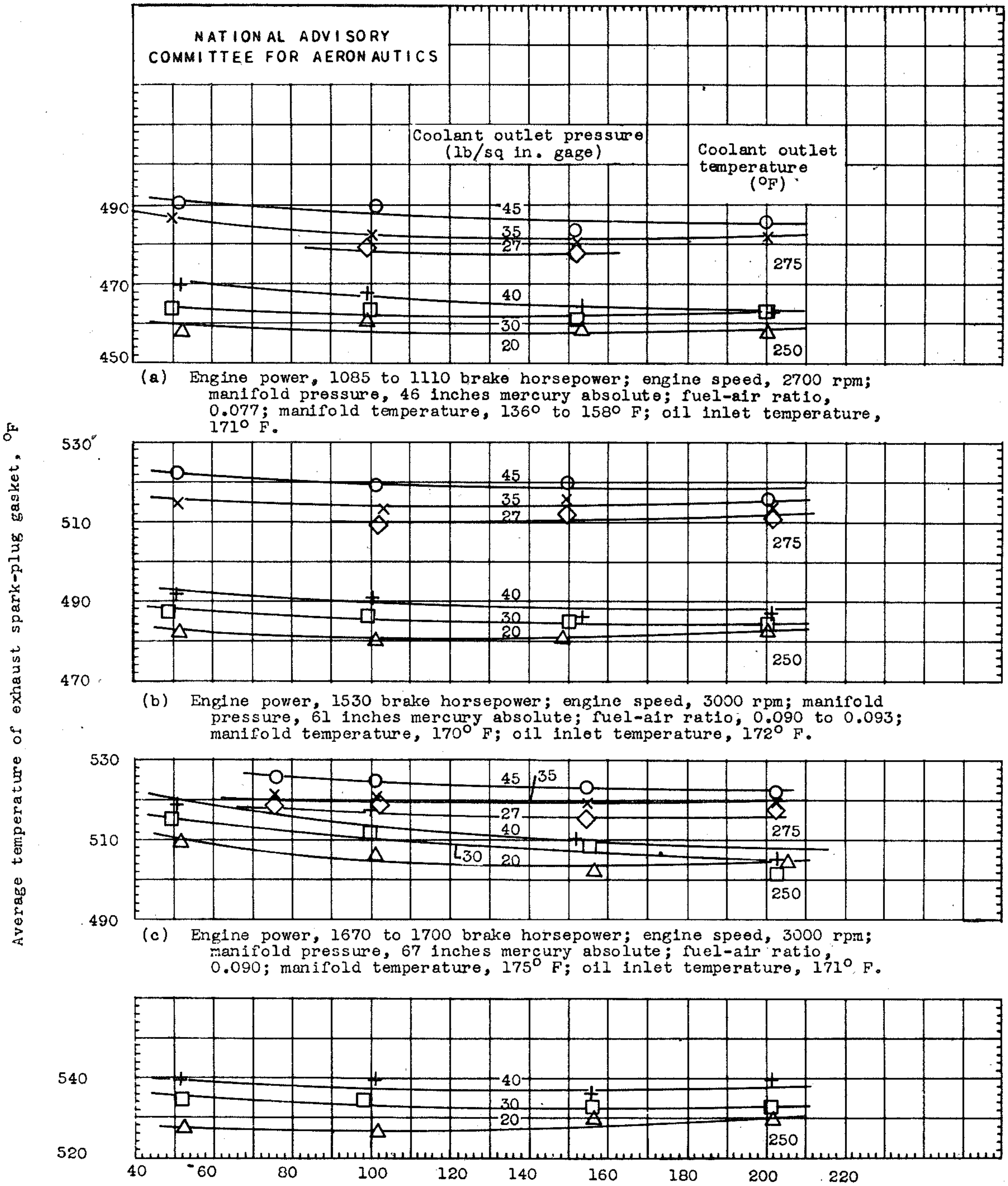
(a) Engine power, 1085 to 1110 brake horsepower; engine speed, 2700 rpm; manifold pressure, 46 inches mercury absolute; fuel-air ratio, 0.077; manifold temperature, 136° to 158° F; oil inlet temperature, 171° F.

(b) Engine power, 1530 brake horsepower; engine speed, 3000 rpm; manifold pressure, 61 inches mercury absolute; fuel-air ratio, 0.090 to 0.093; manifold temperature, 170° F; oil inlet temperature, 172° F.

(c) Engine power, 1670 to 1700 brake horsepower; engine speed, 3000 rpm; manifold pressure, 67 inches mercury absolute; fuel-air ratio, 0.090; manifold temperature, 175° F; oil inlet temperature, 171° F.

(d) Engine power, 2000 brake horsepower; engine speed, 3200 rpm; manifold pressure, 73 inches mercury absolute; fuel-air ratio, 0.092; manifold temperature, 175° F; oil inlet temperature, 170° F.

Figure 10. - Variation of average cylinder-head temperature between the intake valves with coolant flow for several power conditions.



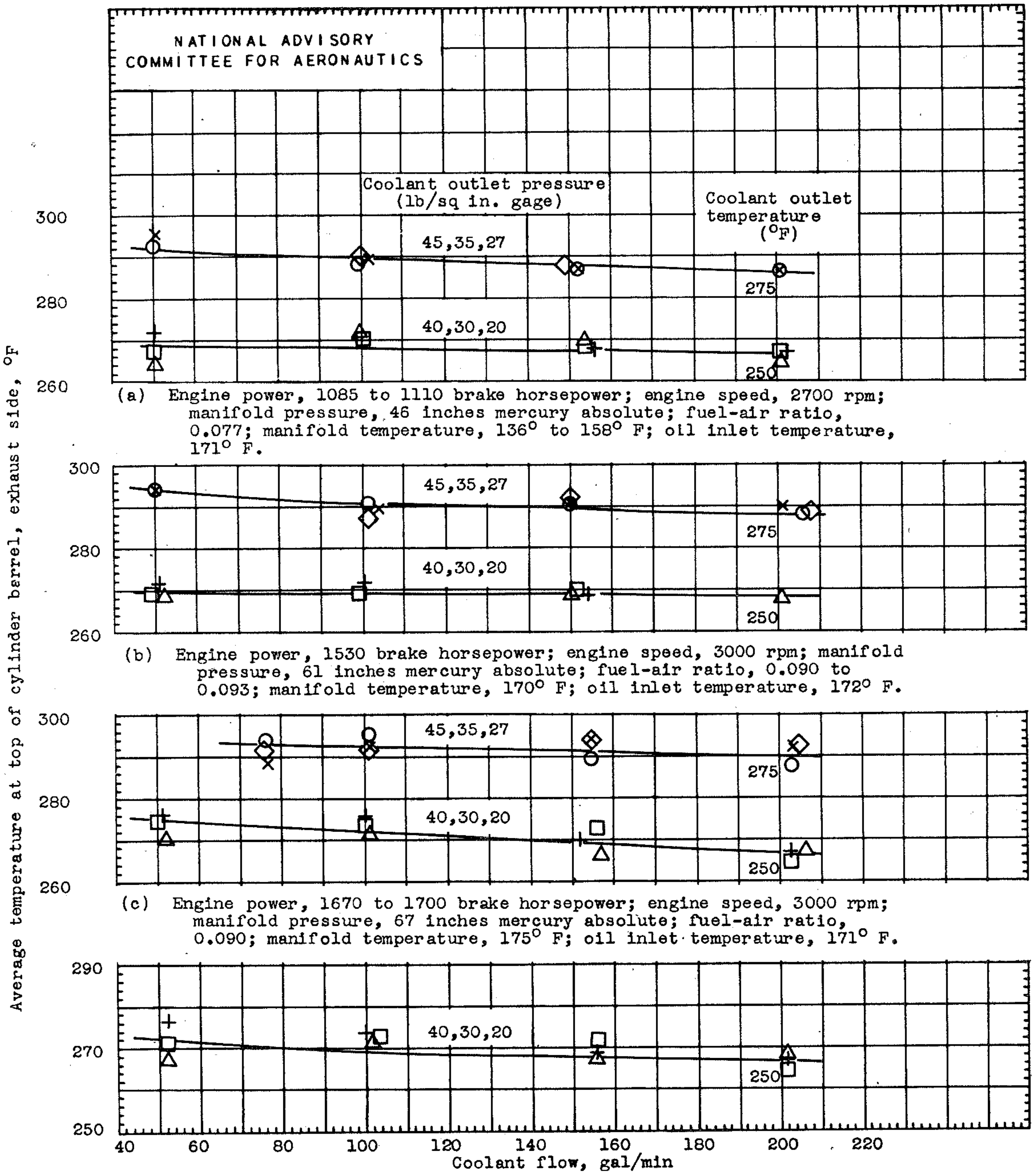
(a) Engine power, 1085 to 1110 brake horsepower; engine speed, 2700 rpm; manifold pressure, 46 inches mercury absolute; fuel-air ratio, 0.077; manifold temperature, 136° to 158° F; oil inlet temperature, 171° F.

(b) Engine power, 1530 brake horsepower; engine speed, 3000 rpm; manifold pressure, 61 inches mercury absolute; fuel-air ratio, 0.090 to 0.093; manifold temperature, 170° F; oil inlet temperature, 172° F.

(c) Engine power, 1670 to 1700 brake horsepower; engine speed, 3000 rpm; manifold pressure, 67 inches mercury absolute; fuel-air ratio, 0.090; manifold temperature, 175° F; oil inlet temperature, 171° F.

(d) Engine power, 2000 brake horsepower; engine speed, 3200 rpm; manifold pressure, 78 inches mercury absolute; fuel-air ratio, 0.092; manifold temperature, 175° F; oil inlet temperature, 170° F.

Figure 11. - Variation of average temperature of exhaust spark-plug gasket with coolant flow for several power conditions.



(a) Engine power, 1085 to 1110 brake horsepower; engine speed, 2700 rpm; manifold pressure, 46 inches mercury absolute; fuel-air ratio, 0.077; manifold temperature, 136° to 158° F; oil inlet temperature, 171° F.

(b) Engine power, 1530 brake horsepower; engine speed, 3000 rpm; manifold pressure, 61 inches mercury absolute; fuel-air ratio, 0.090 to 0.093; manifold temperature, 170° F; oil inlet temperature, 172° F.

(c) Engine power, 1670 to 1700 brake horsepower; engine speed, 3000 rpm; manifold pressure, 67 inches mercury absolute; fuel-air ratio, 0.090; manifold temperature, 175° F; oil inlet temperature, 171° F.

(d) Engine power, 2000 brake horsepower; engine speed, 3200 rpm; manifold pressure, 78 inches mercury absolute; fuel-air ratio, 0.092; manifold temperature, 175° F; oil inlet temperature, 170° F.

Figure 12. - Variation of average temperature at top of cylinder barrel on exhaust side with coolant flow for several power conditions.

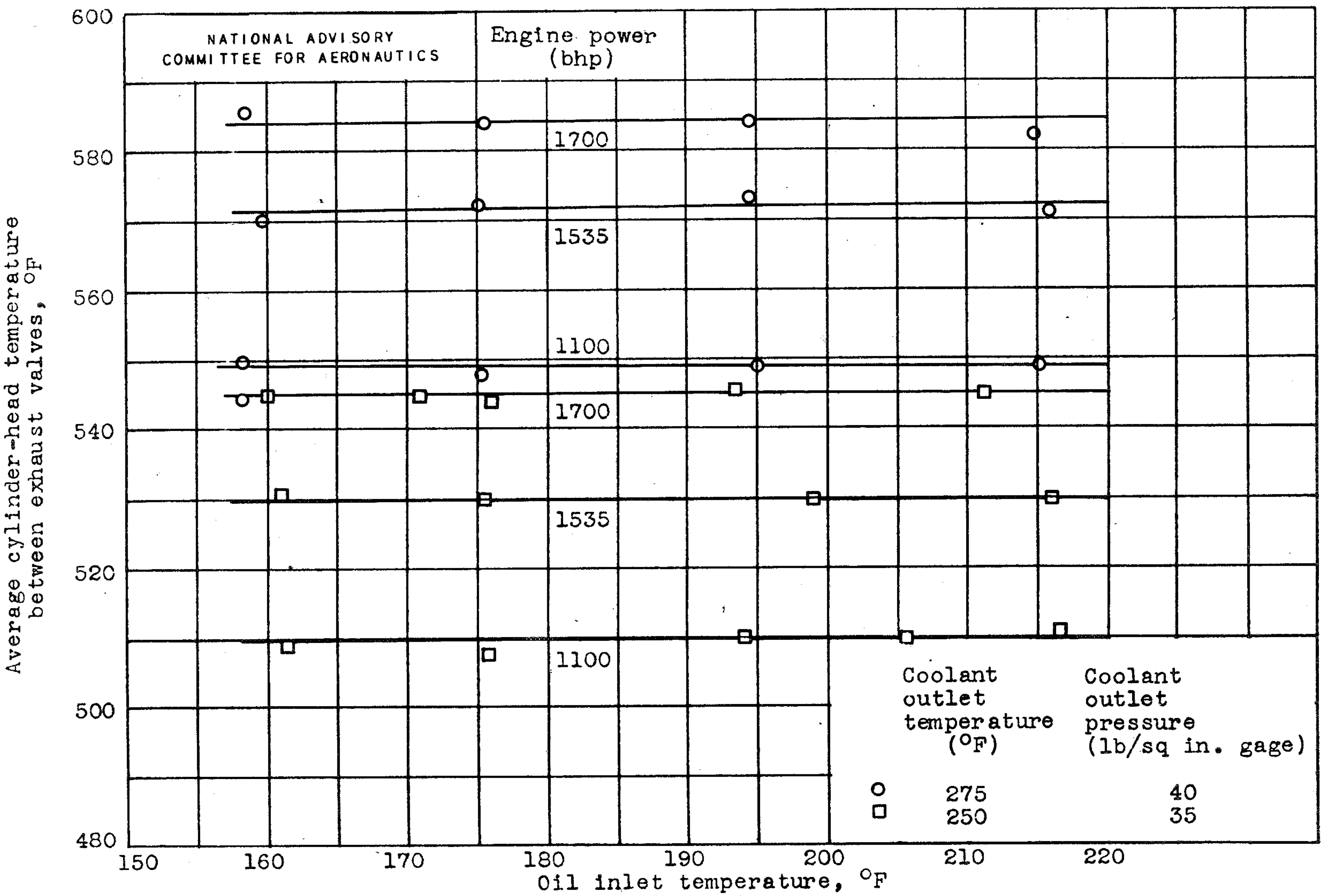


Figure 13. - Variation of average cylinder-head temperature between exhaust valves with oil inlet temperature. Coolant flow, 167 gallons per minute.

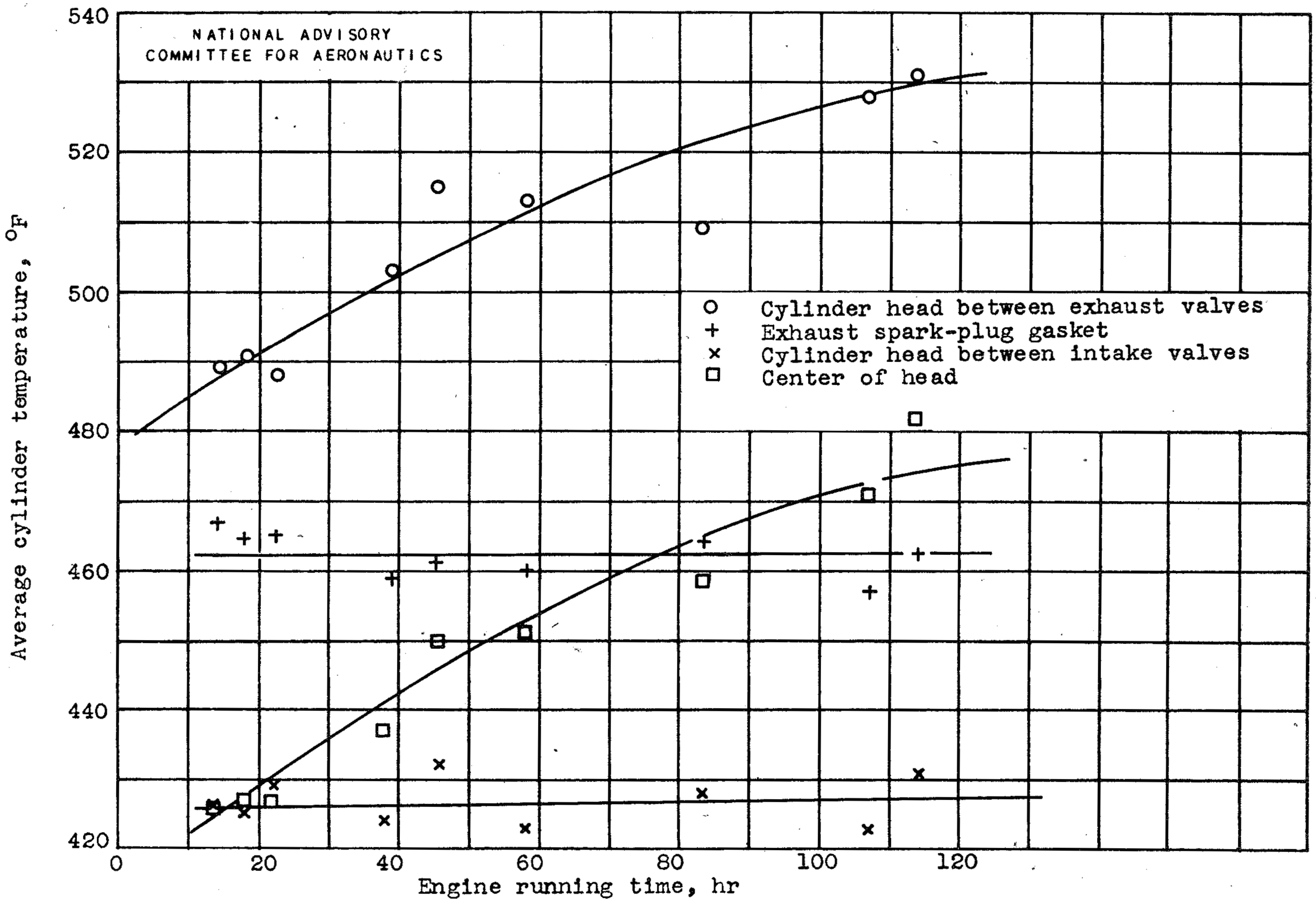


Figure 14. - Variation of average cylinder temperatures with engine running time. Engine power, 1100 brake horsepower; engine speed, 2700 rpm; manifold pressure, 46 inches mercury absolute; fuel-air ratio, 0.080; manifold temperature, 190° F; coolant flow, 200 gallons per minute; coolant outlet temperature, 245° F; block-outlet pressure, 35 pounds per square inch gage.

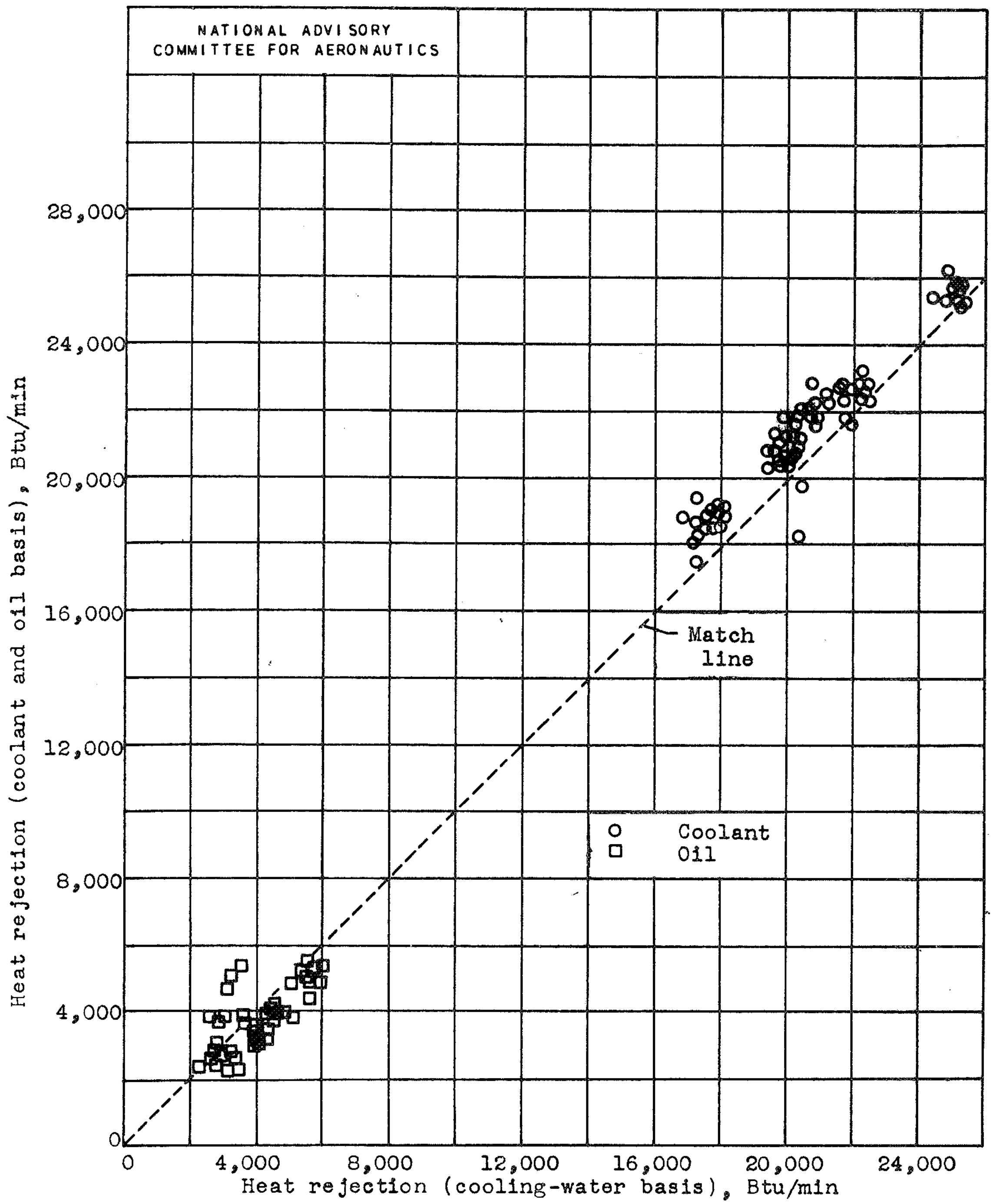


Figure 15. - Heat balance between coolant and coolant-cooling water and oil and oil-cooling water.

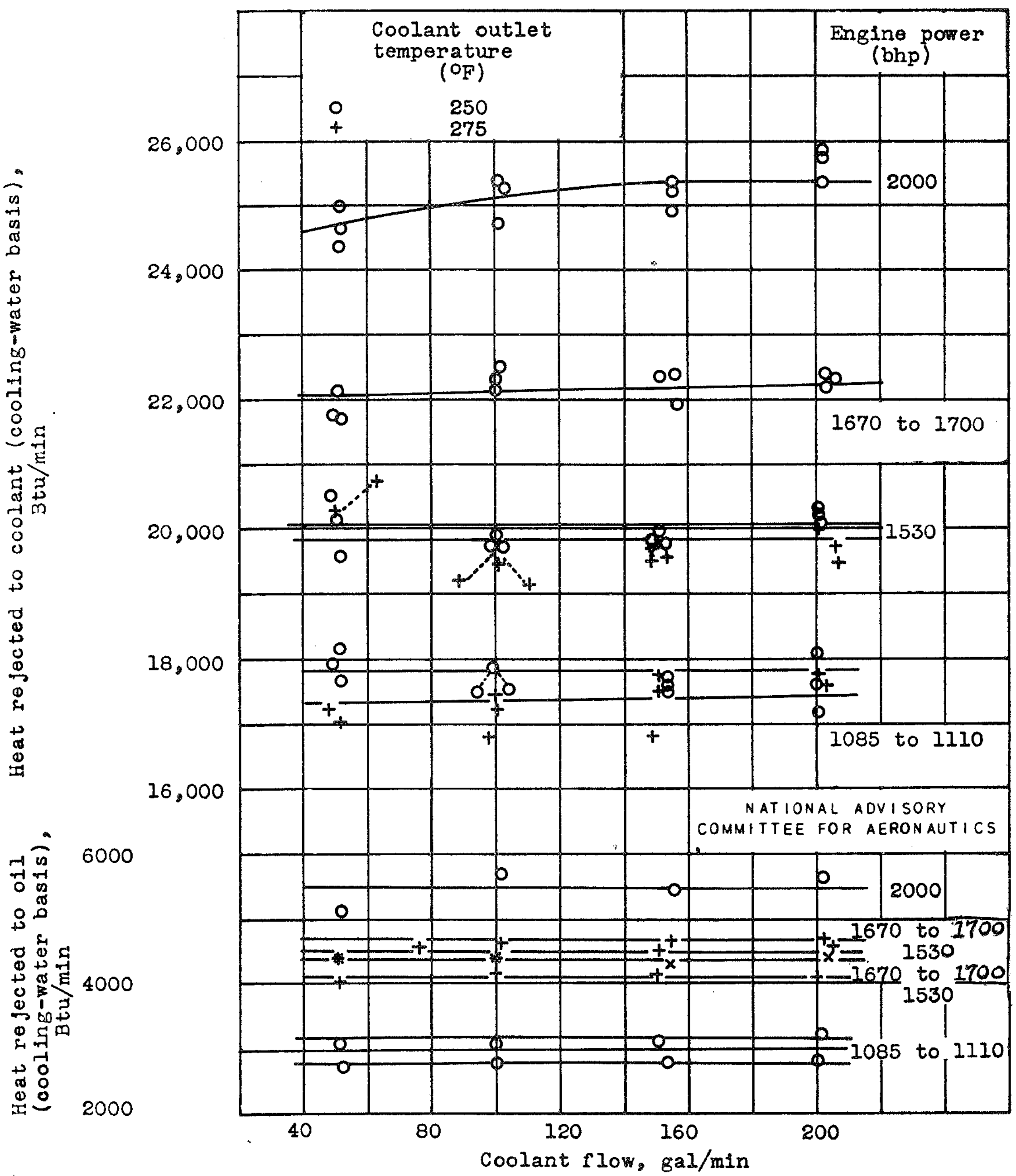
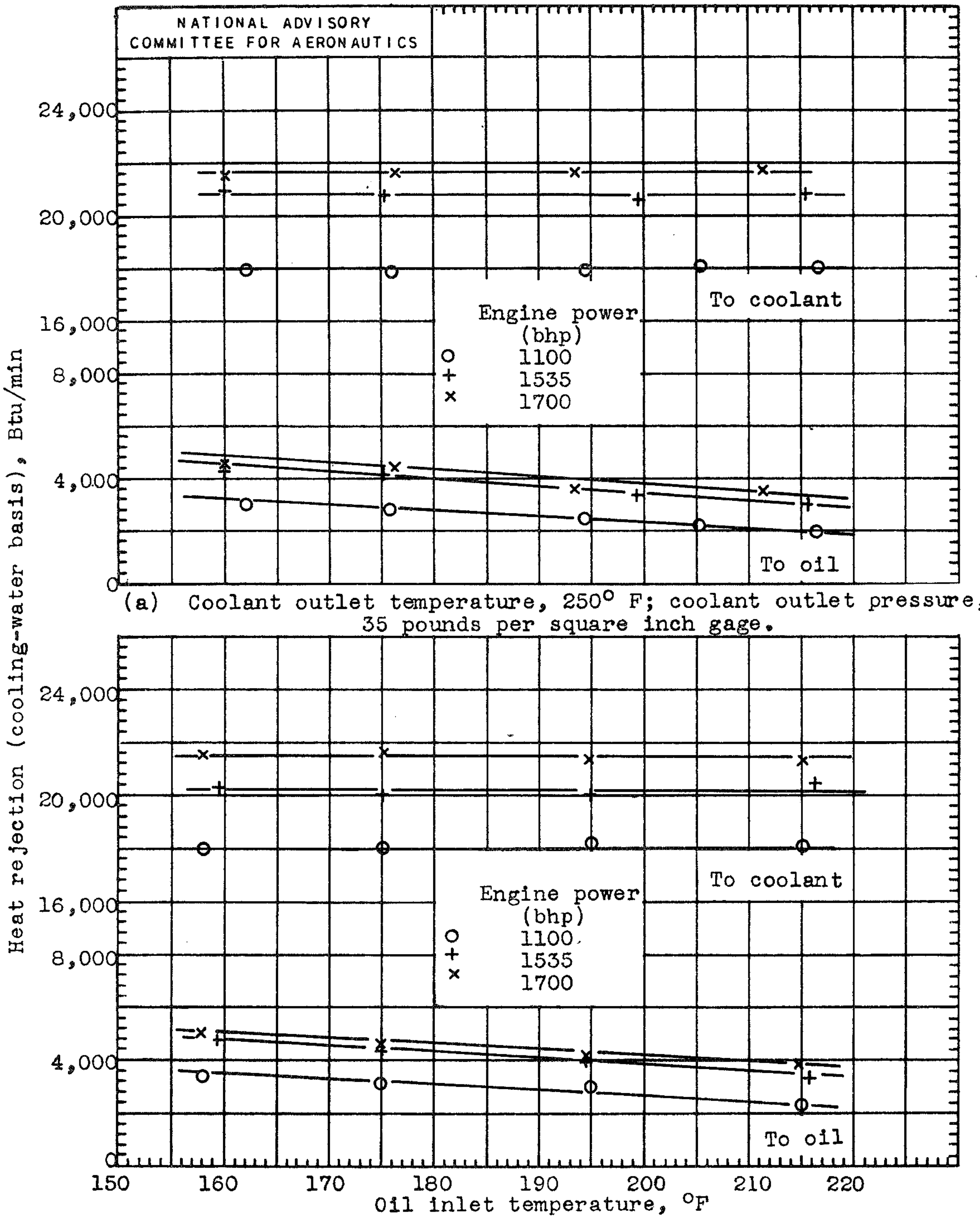


Figure 16. - Variation of coolant and oil heat rejections with coolant flow. Oil inlet temperature, 170° to 172° F.



(b) Coolant outlet temperature, 275° F; coolant outlet pressure, 40 pounds per square inch gage.

Figure 17. - Variation of coolant and oil heat rejections with oil inlet temperature. Coolant flow, 167 gallons per minute.